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A STUDY ON SEDIMENT YEILD OF NAGARJUNA SAGAR RESERVOIR USING GEOSPATIAL TECHNOLOGY

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ABSTRACT

Sedimentation in reservoirs is due to the soil erosion occurring over the catchment area due to various factors like runoff, wind etc. Soil Erosion is a major problem throughout the world and most of soil erosion problem is in areas of agricultural activity where erosion not only leads to decreased agricultural productivity but also reduces water availability. Studies on soil erosion can be conducted using Universal Soil Loss Equations (USLE) and Geo-Spatial technologies. In the present study an attempt has been made to assess the annual soil loss in Upper Nagarjuna Sagar watershed using various factors Viz., Rainfall Erosivity factor (R), Soil Erodibility factor(K), Slope factors(LS), Crop management factor (C), Conservation practices factor (P) etc. The soil loss in the study area is estimated to be 79.735ton/ha/yr and the siltation volume in the Nagarjuna Sagar reservoir is estimated as 4.278 M ton/yr.

***KEYWORDS:** Universal Soil Loss Equation, Rainfall Erosivity Factor, Soil Erodibility Factor, Slope Factors, Crop Management Factor, Sediment Deposit*

Original Article

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INTRODUCTION

The sedimentation in reservoirs is a natural phenomenon and cannot be avoided. The silting process in a reservoir generally starts in the upper shallow waters due to backwater effects and ends as the accumulated silt in the reservoirs. In upper regions of the river flow, the sediment movement is decelerated and consequently the bed load transport is slowed down and the suspension carrying capacity of the flow is reduced and the sediment gets accumulated in the reservoir. Similarly, in the case of Nagarjuna Sagar multi-purpose reservoir which is the study area for this paper, the storage capacity of the reservoir is reduced to about 80.5% of its designed capacity [3] due to the continuous siltation over a period.

The siltation process is aggravated by the soil erosion due to the combination of various factors of the catchment area such as slope steepness, climate (e.g. long dry periods followed by heavy rainfall), inappropriate land use, land cover patterns (e.g. sparse vegetation) and ecological disasters (e.g. forest fires). Remote Sensing (RS) and Geographical information System (GIS) tools along with USLEs are effectively utilized to study the state of art of siltation in the Nagarjuna Sagar Reservoir.

Study Area

Nagarjuna Sagar is one of the major multi-purpose river valley project on river Krishna connecting Nalgonda district of Telangana state and Guntur district of Andhra Pradesh state. The River Krishna flows with its tributaries Tungabhadra, Vedhavati, Hundri, Musi, Paleru and Munneru in both the states and drains into Bay of

Bengal. The purpose for which Nagarjuna Sagar is constructed is to provide irrigation facilities to about 9 lakh hectares of parched lands and to develop seasonal power of 960 Megawatts per year. The project comprises of a dam with two main canals taking off, one on either side, viz., the Left Main Canal and Right Main Canal. The Study area considered is the portion located in between the Nagarjuna Sagar Reservoir and the Srisailam Dam, another river valley project located in the upstream side of the Nagarjuna Sagar project, with a catchment area of 9791.7930 km^2.

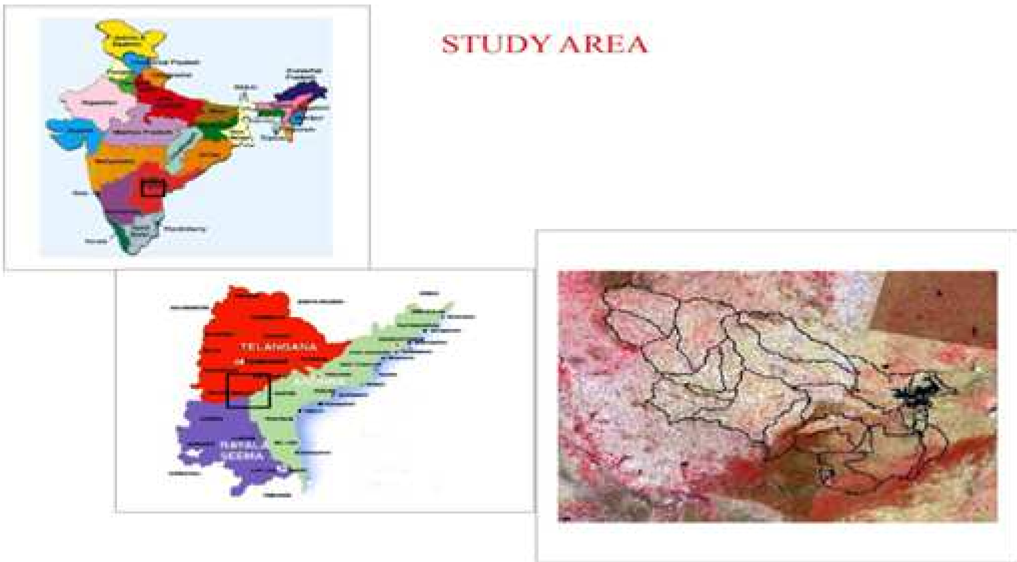

Figure 1: Study Area

METHODOLOGY

The soil loss from the study area is calculated using the following USLE (Universal Soil Loss Equation), for the existing vegetative cover over the catchment area.

A=R * K *LS * C * P --------- (Eq.-1) [Wischmeier, W.H et.al (1965)[7]**]**

Where

A - Average Annual Soil Loss (ton/ha/yr)

R - Rainfall Erosivity factor (in MJ mm/ha/hr/yr).

K - Soil Erodibility factor

L - Slope length factor

S - Slope Steepness factor

C – Crop management factor

P – Support Conservation Practice factor

The evaluation of above cited factors and the computation of the soil loss from the study area have been conducted as shown in the following flow chart.

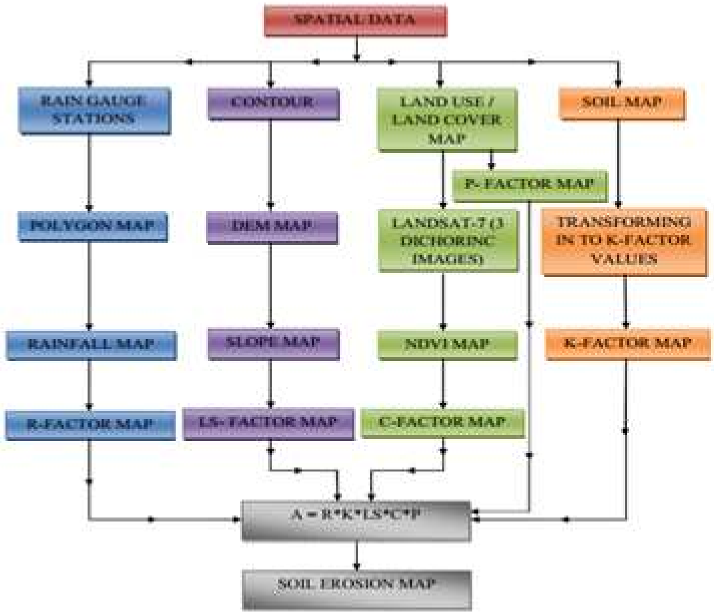

Figure 2: Methodology of the Present Study

The rainfall factor (R) used in the USLE equation is derived from the relationship as given below. A 5-year average annual data has been used to calculate the average annual R-factor values.

R= 79+0.363 Rn ---------- (Eq.-2) [Reshma Parveen et.al (2012)[4]**]**

Where: Rn is Average Annual Rainfall in mm.

R is the Rainfall Factor

The Soil Erodibility factor (K) is obtained from the soil map of the study area is prepared based on National Bureau of Soil and Land use planning standards. [4]

Topographic Factor (LS) is evaluated using the relationship integrated with GIS by incorporating the Digital Elevation Models of the catchment area and based on unit stream power theory. In the present study, 30 m ASTER DEM has been used. Raster calculator was used to derive LS map based on flow accumulation and slope steepness. The expression used is as follows:

LS = Power ([flow accumulation] resolution/ 22.13, 0.6) × Power (Sin ([Slope of DEM] ×0.01745 / 0.0896, 1.3) ------------------ (Eq.-3) [H. Mitasova et.al (1999)[1]**]**

The Crop management factor (C) is determined using the following equations with remote-sensing derived indicator of vegetation growth i.e., the Normalized Difference Vegetation Index (NDVI) as given below and the NDVI images of the study area.

NDVI = $\frac{\mathbf{NIR-IR}}{\mathbf{NIR+IR}}$ **--------------- (Eq.-4) [**Reshma Parveen et.al (2012)[4]**]**

Where

NIR: The reflection of the near infrared portion of the electromagnetic spectrum.

IR: The reflection in the visible spectrum.

$$C = \exp\left(-\alpha\frac{NDVI}{(\beta - NDVI)}\right) \text{ ----------------- (Eq.-5)}$$

Where

α and β are unit less parameters (2 and 1 respectively).

The supporting Conservation practice factor P is obtained from the standards. [3, 4]

The Siltation Rate is calculated using the Khosla's equation [2, 6] for Deccan plateau as given below.

Khosla's Equation

$$Q_s = 0.00323A^{0.72} \text{ ------------- (Eq.-6)}$$

Where

Q_s = Siltation rate, Mm^3/year

A = Catchment area, km^2

RESULTS AND DISCUSSIONS

Rainfall Erosivity Factor (R)

The average annual rainfall data of nine surrounding rain gauge stations was used to get the rainfall distribution map of the entire watershed. The average annual rainfall in the study area varied between 677.18 mm to 1295 mm. The spatial distribution of rainfall erosivity factor (R) map (Figure 3) was generated in Arc-GIS from average annual rainfall map. The erosivity factor varied from 321.127 – 398.034 MJ ha/mm/hr/yr.

Soil Erodibility Factor (K)

Soil Erodibility factor map (Figure 4) was prepared from soil map of the study area based on different soil textures and the K values at different locations in the study area are as follows (table 1)

Table 1: Soil Erodibility Factor (K) Values of the Study Area

Station No	Name	K_Factor
1.	Devarakonda	0.19
2	Veldurthi	0.20
3	Sunnipenta	0.21
4	Mahabubnagar	0.14
5	Charakonda	0.21
6	Hyderabad	0.08
7	Markapuram	0.24
8	Chintakunta	0.21
9	Nalgonda	0.27
10	Hasanbad	0.21
11	Rapole	0.16
12	Macherla	0.21

Topographic Factor (LS)

Slope and flow accumulation grid was prepared from ASTER DEM. Since USLE is only applicable to rill and inter-rill erosion, there should be an upper bound to slope length. To enforce such an upper bound the flow accumulation grid was modified to make sure the flow length did not exceed 180 m, which is a reasonable flow length. Since DEM has a

resolution of 30 × 30 m; and as the flow accumulation cannot exceed 6 grid cells, all cells with flow accumulation greater than and equal to 6 were assigned the value 6. Slope was calculated using the available slope function in ARCGIS. Using ASTER DEM derived flow accumulation and slope grid, a LS-factor map was created, which is shown in Figure 5. LS factor values ranged from 0.029 to 31.545. However, major portion of the area is in the range of 0.029 to 3.09.

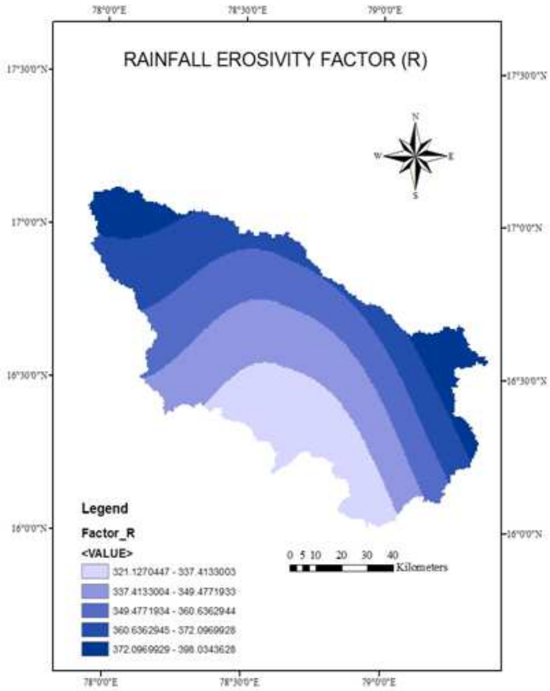

Figure 3: Rainfall Erosivity Factor (R) Map of the Study Area

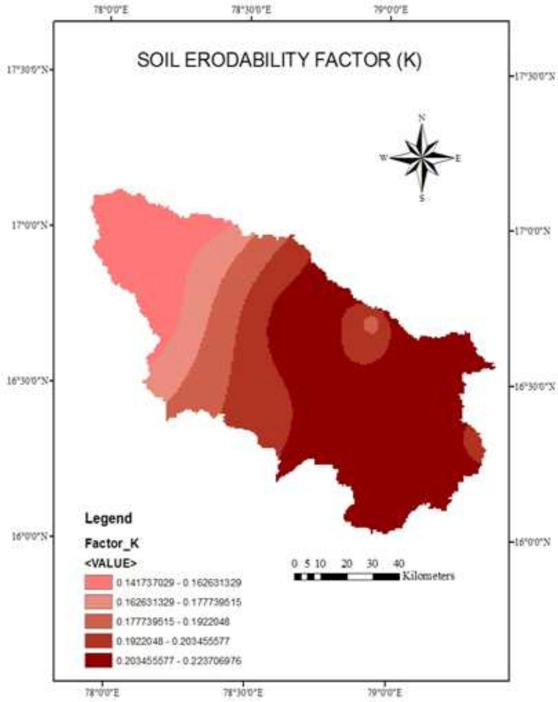

Figure 4: Soil Erodibility Factor (K) Map of the Study Area

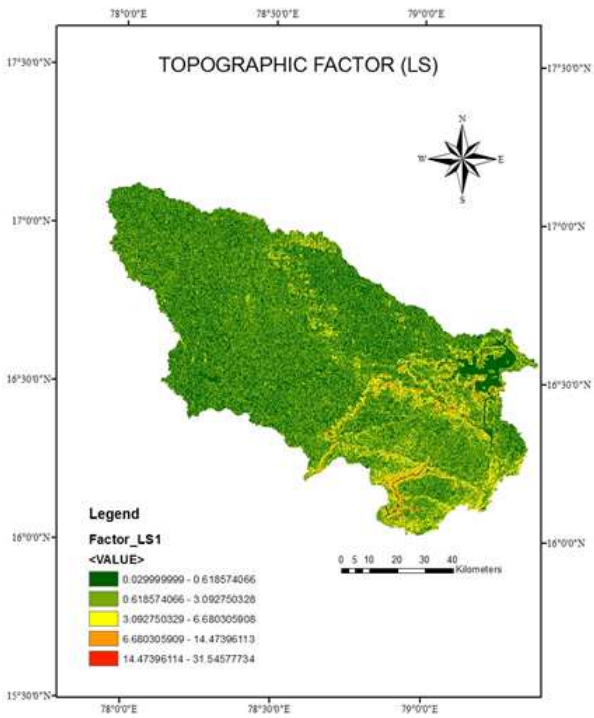

Figure 5: Topographic Factor (LS) Map of the Study Area

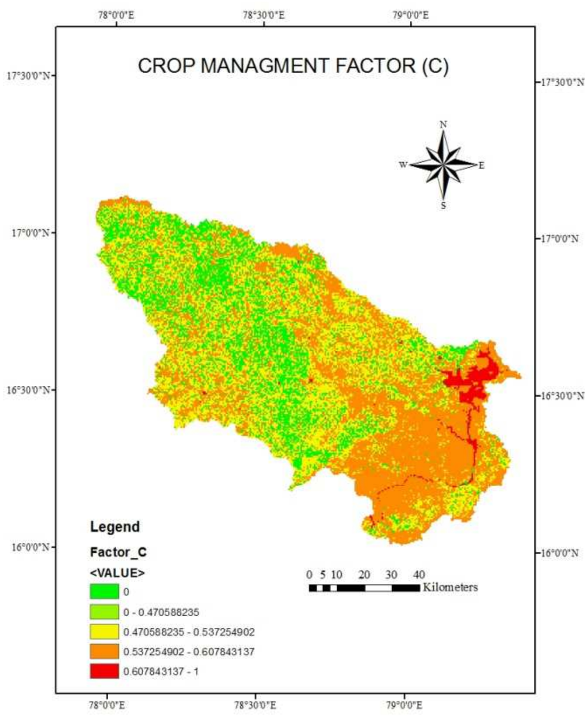

Figure 6: Crop Management Factor Map(C) of Study Area

Crop Management Factor (C)

Using the NDVI image derived from Landsat TM satellite data of the study area C factor map was generated as shown in Figure 6. The C factor values in the study area varied between 0 to 1. For the dense vegetation areas, C values varied from 0.0 to 0.47 and for water the values approached 1. The C values ranged from 0.47 to 0.53, 0.53 to 0.60, and

0.60 to 0.69, for agricultural areas, shrub lands and forest with less canopy in the study area respectively. The Conservation Practice Factor (P) all the land uses was assigned as 1.

Annual Soil Loss Mapping

Figure 7 shows annual erosion map of study area, and is helpful in identification of areas vulnerable to soil erosion. The mean annual soil loss estimated for the entire watershed is 79.735 ton /ha/yr. Major portion of the watershed is found to lose the soil at the rate of 0 to 2 tons/hec/year.

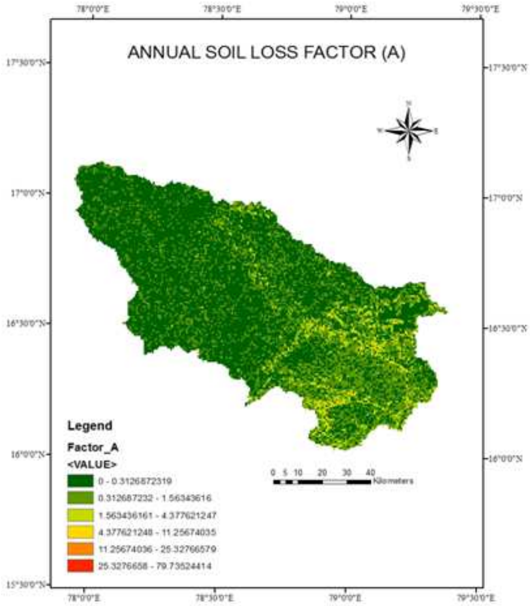

Figure 7: Annual Soil Loss Map (A) From the Study Area

Siltation Rate

The density of sediment in reservoir is taken as 1770Kg/m^3 and the sedimentation is computed by the Khosla's equation as mentioned earlier.

$Q_{sv} = 0.00323A^{0.72} = 0.00323(9791.7930)^{0.72} = 2.413 Mm^3/yr$ (4.278 MT/yr).

Where

Q_{sv} = Siltation rate, Mm^3/yr

A = Catchment area, km^2

CONCLUSIONS

- The mean annual soil loss of the study area is estimated to be 79.735 ton /ha/yr. Major portion of the watershed is found to lose the soil at the rate of 0 to 2 tons/hec/year.
- The siltation rate into the reservoir is found to be 4.278 MT/yr.
- The reservoir capacity is estimated to be reduced by 0.11% with the above cited siltation rate.

REFERENCES

1. *H. Mitasova and L. Mitas, “Modeling Soil Detachment with RUSLE 3d Using GIS,” University of Illinois at Urbana-Champaign, 1999.*
2. *Khosla A.N., “Silting of Reservoir”, New Delhi Publication No. 51. CBIP (1953).*
3. *R.S. Reddy, S.K. Nalatwadmath and P. Krishnan (2005) "Soil Erosion Andhra Pradesh"*
4. *NBSS Publ. No. 114, NBSS&LUP, Nagpur, 76 pp.*
5. *Reshma Parveen, Uday Kumar (2012) “Integrated Approach of Universal Soil Loss Equation (USLE) and Geographical Information System (GIS) for Soil Loss Risk Assessment in Upper South Koel Basin, Jharkhand” Journal of Geographic Information System, 2012, 4, 588-596*
6. *S. Venkateswara Rao et.al (2014) “Reservoir Sedimentation and Concerns of Stakeholders” Research Journal of Engineering Sciences Vol. 3(2), 29-32, February (2014) ISSN 2278 – 9472.*
7. *Upadhyay Rahul et.al (2012) “Annual Sedimentation Yield and Sediment Characteristics of Upper Lake, Bhopal, India” Research Journal of Chemical Sciences vol. 2(2), 65-74, Feb. (2012) ISSN 2231-606X.*
8. *Wischmeier, W.H., and D.D. Smith. (1965). “Predicting Rainfall-Erosion Losses” From Croplarzd East of the Rocky Mountains, U.S. Department of Agriculture, Agriculture Handbook No. 282, 48 p.*